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ARTICLE XIII.

Contributions to the Geology of the Tertiary formations of Virginia.
—Second Series. By William B. Rogers, Professor of Natural
Philosophy in the University of Virginia, and Henry D. Rogers,
Professor of Geology and Mineralogy in the University of Penn-
sylvania. Read March 1, 1839.

GEOLOGY OF THE PENINSULA BETWEEN THE POTOMAC AND RAPPA- HANNOCK RIVERS.

THE portion of the state referred to under this head, embraces the counties of Lancaster, Northumberland, Richmond, Westmoreland and King George, together with the eastern part of Stafford county, thus including the district usually denominated the Northern Neck, and extending some distance beyond it to the west.

This area forms the northern portion of the tertiary region of Virginia, presenting extensive deposits of each of the two subordinate divisions of the tertiary formation, which were described in our former paper as occupying the tidewater districts of the state. The more recent of these subordinate formations, the *meiocene*, or middle tertiary, extends from near the bay shore, westward, over the larger portion of the peninsula; while the older, or *eocene* deposit, occupies the remaining area on the west. The precise boundaries of these formations, as recently determined, will be hereafter described.

Topographical Features.

The general aspect of the peninsula, and more especially of the four eastern counties, is that of a nearly level plane, maintaining an average elevation of from sixty to seventy feet above the tide. This plane, gently furrowed by numerous ravines, subordinate to the creeks and inlets indenting the peninsula, frequently subsides to a lower level, in approaching the rivers on either side. The wide *bench* thus formed, sometimes extends in a direction parallel to the river for a distance of several miles, presenting an unvarying uniformity of elevation, and reaching nearly to the water's edge. A third, and lower plane frequently intervenes between the river bank and the table land above described, but in many cases this *terraced* configuration of the surface is not observed, and the high and precipitous cliffs which rise very near the water's edge, retain the general level of the inland portion of the peninsula. Although the usual elevation of this district is such as above described, at several points a far higher level is attained. The ridge which forms the water shed of the streams flowing into the Potomac and Rappahannock, approaching very near to the former, constitutes, in some places, the river bank. At these points it attains an unusual elevation, towering, as at Stratford and Chantilly, to a height of about one hundred feet above the water's edge, and affording from its summit an extensive and enchanting view of the noble river which laves its base, of the cultivated farms around, and of the cliffs on the opposite, or Maryland side of the Potomac. At Sprize Hill, about four and a half miles from Smith's Point, the ridge bends round to the south, and continues for some distance in a direction across the peninsula, preserving an elevation of about sixty feet. Its declivity on the east forms an abrupt termination of the higher level of the neck, between which and the bay shore is an extensive flat, of from two to four miles in width, rarely rising beyond the height of ten feet above the level of the tide, and in some places so low as to be occasionally overflowed.

The western portion of the peninsula, though still, in the main, presenting a similar uniformity of surface, is somewhat more abruptly furrowed. This inequality, increasing as we proceed further to the west,

becomes quite conspicuous at the Paspitansy hills, in King George, and in the neighbouring parts of Stafford county, adjacent to the line of secondary sandstone, which forms the western limit of the tertiary formation.

The material forming the superficial strata, in the lower portion of the peninsula, is usually a mixture of sand and clay, in a state of minute subdivision, and more or less tinged with the oxide of iron. Sometimes this is intermixed with small gravel, of a ferruginous appearance, but it rarely contains pebbles or boulders of any notable dimensions. The diluvial matter assumes a coarser texture, as we proceed westward, presenting, when denuding forces have not removed the superficial beds, alternate strata of sand and pebbles, the latter varying from a half inch to several inches in diameter. In many places these boulders, derived in great part from the neighbouring beds of sandstone, are strewn profusely over the surface, and, together with the superficial layers of white and siliceous sand, render the soils of the higher portions of this district comparatively unproductive. While upon the lower levels, contiguous to the large rivers, or their tributaries, the beds of marl, and their associated sands and clays, mingling their fertilizing materials with the soil, have contributed to impart to it a far higher agricultural value.

Of the Limits of the Miocene and Eocene Districts of the Peninsula.

Bounded on the west by the secondary sandstone, before referred to, the eocene formation extends eastward for some distance down the neck, until at length, with a very gentle eastern dip, it disappears below the level of the tide. The most eastern points in which it continues visible, are here regarded as forming the boundary of the formation towards the east, and the district included between a line traced through these points and its boundary to the west, is, for convenience sake, designated as the Eocene district; although, at some places within its confines, as in the peninsula of the James and York rivers, beds of miocene occur overlying the eocene.

In tracing the boundary of the eocene and miocene marls, as exposed in the neck, several localities, marking the eastern termination of the former deposit, were carefully inspected in the anticipation of discovering beds of miocene shells above them, or immediately be-

yond them to the east. It was found, however, that strata of clay, lying adjacent to the eocene on this side, occupied an interval in which fossils of neither of these formations could be distinctly found; and that still further on, the beds of the meiocene came in view. This intervening tract, as seen upon the Potomac and Rappahannock, is flat and low.

Without, then, pretending to an exact delineation of the boundary in question, which, from the nature of the case, would be impracticable, it will be sufficient for the present to consider it as coincident with a right line, connecting the mouth of Chingoteague creek on the Rappahannock, with Mathias's Point upon the Potomac. A brief account of the character and situation of the strata, as observed at these two points, will serve to illustrate the propriety of fixing upon them as its termination.

To the west of the mouth of Chingoteague creek, for a distance of more than half a mile, the north bank of the Rappahannock has an average height of about fifteen feet above the river. At its upper end this bank consists of a stratum of the green sand marl, extending to the height of twelve feet above the water line, upon which reposes a layer of diluvial sand and clay, about three feet in thickness. In approaching the creek, the level of the marl stratum is observed steadily to decline, while the thickness of the incumbent bed augments until, at a point within two hundred yards of the mouth of the creek, the former entirely disappears below the level of the river. At this point the diluvial capping is about fourteen feet in thickness, consisting of a layer of sand and pebbles about seven feet thick, resting upon a stratum of whitish clay, which reaches to the water line.

The eocene character of these subjacent beds is unequivocally marked. At the base of the bank a dark greenish layer presents itself, rising to the height of five or six feet, containing numerous impressions of the eocene *Carditas*, and other shells of a brownish colour. Over this is a layer of a lighter hue, containing bands of white calcareous matter, obviously the remains of shells.

To the east of Chingoteague creek the bank preserves its former height for about three-fourths of a mile; after this it becomes much depressed, and continues to be low for some distance down the river.

Here no trace of fossils of either the eocene or miocene period could be discovered, the bank consisting exclusively of diluvial sand and gravel. But still further down the river, beds of the latter are observed, and these continue, at intervals, to near the extremity of the peninsula.

An equally marked termination of the eocene is presented in the neighbourhood of Mathias's Point, on the Potomac. At Woodstock, about one-third of a mile above the Point, the cliffs rise to the height of from forty to fifty feet, exhibiting an exposure of the eocene strata, reaching to a distance of nearly twenty-five feet above the surface of the river. The lower bed, about eight or nine feet thick, is rich in the fossils characteristic of the eocene, but the layer, incumbent on this, though filled with ferruginous impressions of shells, retains none of the shells in an unchanged condition. The bed of reddish clay which forms the upper portion of the bank, is separated from the strata just described by a thin band of ferruginous gravel and sandstone, such as is frequently seen occupying a similar position on the Pamunky and in other localities.

Above this place, on the adjacent estate called "Borodino," the residence of Mr Parke, the banks, after sinking to a level with the flats, again rise, with some abruptness, to an elevation of from forty to sixty feet. The lower stratum of the marl, containing shells in considerable number, is here but little raised above the level of the water. A layer deeply tinged with green sand, and blotched with oxide of iron, rests on this to the height of from four to five feet. Another, but not fossiliferous bed, belonging to the same series, reposes upon the latter, but the piles of fallen earth at present preclude an accurate examination of its character and extent. Still further westward, at "Albion," the estate of Mr Mason, the fossiliferous eocene strata vary from four to seven feet in height above the river, and are overlaid by heavy beds of whitish and mottled clay. Strata recur, at intervals, in ascending the river, rising to greater elevations, and presenting a greater abundance and variety of fossils as we proceed.

Below Woodstock the banks gradually decline, and on the side of a little creek or gut between this and Mathias's Point, the eocene strata entirely disappear. To the east of this creek and at the Point, the

banks rise to twenty or twenty-five feet, and consist of yellowish and reddish clays, containing no trace of the green sand or fossils of the eocene. Still further down, the cliffs are replaced by a low and retiring shore, beyond which the beds of meiocene marl first come in view.

It is obvious from these details, that the eastern limit of the eocene is marked on both rivers by the occurrence of a region of like geological and topographical features, immediately east of it, and by great similarity in the arrangement and composition of the contiguous strata. As on the James and Pamunky rivers, as well as in the district of which we are now treating, the eocene is skirted on the east by a level and comparatively low district, comprising only beds of sand and clay, destitute of fossils. It would seem a probable conclusion that these barren strata mark the period of disturbance which terminated the epoch of the eocene deposits, a period attended with such important changes in the condition of the neighbouring seas, as to destroy all, or nearly all, the species of shell fish then inhabiting them, and to adapt their waters to that multitude of new species which were brought to light in the succeeding epoch of the meiocene.

Between the two points thus fixed upon as the extremities of the eastern boundary of the eocene in the neck, several intermediate localities have been marked, but from the obscurity of the exposures, no very certain indication could be derived as to the precise figure of the boundary line, in the intervening space. There is little doubt, however, that it will be found to depart but in a very slight degree from the right line connecting the two points above described.

The *western boundary of the eocene* remains next to be described. In drawing the line of demarcation here, as in the former case, a few well determined points are relied upon for fixing its general direction, and the intervening irregularities are not attempted to be laid down. Indeed the absence of any satisfactory exposures of the strata, throughout a distance sometimes of several miles, renders this the only method of proceeding at present practicable.

The guiding points, in fixing the western limits of the eocene in the peninsula, are:

First, The mouth of Massaponax river, in Spotsylvania county.

Second, The plantations of Mr Bowen and Dr Welford, in Stafford county, opposite to Fredericksburg, somewhat more than a mile from the town.

Third, A locality near, but a little east of Stafford.

Fourth, A point on Acquia creek, about one mile below the mouth of Auston's Run.

Fifth, A point on the Potomac, between Cook's Landing and the mouth of Meadow Branch.

An inflected line, passing through these points, will present a close approach to the actual boundary of the eocene, in this portion of the state.

On the west side of the mouth of Massaponax, the freestone, which constitutes so valuable and interesting a feature in the geology of this district, terminates, and at a short distance below, eocene strata come distinctly into view. Where the main road leading down the Rappahannock crosses the Massaponax, the greenish yellow bed, which frequently forms the highest stratum of the eocene, may be plainly discerned in the hill side, its clayey texture turning off the water, which makes its escape along its upper surface.

On Snow creek, on the edge of Spotsylvania county, and less than a mile to the east of Massaponax, several extensive exposures of the eocene occur. Near the point at which the road before mentioned crosses the creek, a bank of from thirty to forty feet in height exhibits the following series:

1. A dark bluish green stratum, containing a little sulphate of lime, a considerable proportion of green sand, and a great many shells, among which are eocene *Cardita* (*planicosta*?), *Cytherea ovata* (*nobis*), *Turritella Mortoni*.

2. Stratum of greenish yellow, and somewhat micaceous clay, containing some sulphate of lime, and a little sulphate of iron, or copperas.

3. Stratum of a yellowish brown mixture of clay and sand, with ferruginous markings, indicating the former places of shells. This contains a small amount of sulphate of lime.

4. An upper bed of diluvial sand and gravel.

On the same stream, nearer the river, and at the base of the first low grounds, another exposure occurs, which, from the peculiar con-

dition of the fossils it contains, merits a description in this place. The strata are follows:

1. A layer, consisting of common and green sand, the latter in remarkably large grains, and amounting to more than twenty per cent of the whole. A striking feature in this stratum is the immense number of fossils, principally *Cytherea ovata (nobis)* and *Turritella Mortoni*, which it contains in the modified condition before described. The shelly matter has almost entirely disappeared, and its place is now occupied by oxide of iron, of a deep brown colour, presenting the most perfect casts, both of the interior and exterior of the shells. This bed contains a notable proportion of green sand, a little mica, and some sulphate of lime and of iron. Its thickness is about eight feet.

2. A stratum of yellowish white sand, variegated with numerous bright yellow blotches, faintly representing the figures of the shells which they have replaced. These blotches are principally composed of oxide of iron. The chief material of this bed is common siliceous sand, containing a few scattered granules of green sand. Its thickness is about twenty feet.

3. Diluvium, containing coarse gravel, and some large pebbles.

The localities in Stafford, opposite to Fredericksburg, forming one of the landmarks of the eocene, above enumerated, are situated near a branch of Claiborne's Run, on a meadow. On Mr Bowen's place a pit has been dug, in which the following strata are exposed:

1. A bed consisting of green sand mingled with common sand, being the upper layer of the eocene, and, as might be expected, containing no shells.

2. Two feet of sand and pebbles, mostly of white quartz.

3. Six feet of yellowish and reddish clay.

At Dr Wellford's, about one-third of a mile distant from the former, a bed of sand and clay, of six feet thickness, is first penetrated. Beneath this is found a band of iron sandstone, six inches thick, and immediately below this the upper stratum of the eocene.

At the other points above enumerated, exposures of considerable extent occur, chiefly differing from the foregoing in the larger amount of calcareous matter which they present, and in the usual presence of shell rock in one or more of the strata. At an inconsiderable distance

to the west of these points, the beds of freestone make their appearance.

On the Accakuk, near Mr Brookes's, the eocene and sandstone are seen at very contiguous points, both presenting exposures of considerable extent. The marl here consists chiefly of shells, imbedded in a dark olive brown clay, containing a portion of green sand. The shells are chiefly *Cytherea*? and *Ostrea sellæformis*, with a few *Cardita planicosta*? At Mrs Roll's, on Acquia creek, about two miles below the mouth of Auston's Run, the marl is finely exposed, in an abrupt cliff. Here fine specimens of *Turritella Mortoni*, *Cytherea ovata (nobis)*, *Crassatella (nobis)*, *Ostrea sellæformis*, may be readily procured. The material in which they are imbedded is a friable mixture of sand and clay, of a light yellowish brown colour, blended with green sand, in granules of unusually large size.

In thus drawing an outline of what may be termed the western coast of the eocene formation, it is necessary to remark that the peculiar irregularities observed at several points in the line of actual boundary, will occasion considerable discrepancies between it and the line above described.

Besides such flexures as may have originally existed in this line at the period of the deposition of the eocene, great additional irregularities must have been produced by the destructive agencies which subsequently operated. The region in which the freestone and eocene formations are brought together, is marked by the effects of violent diluvial action. Coarse gravel, pebbles and boulders bestrew the surface, and mingle to considerable depths with the sandy strata usually found upon the heights. Deep and precipitous ravines, connected with the valleys of the creeks leading into the Potomac, attest the energy and extent of the aqueous forces once operating over this region, while the confused mixture of materials, by which the usual upper stratum of the eocene is often seen to be replaced, indicates the power of the denuding and transporting agencies to which that formation must at one time have been exposed. It is thus that many places within the general confines of the eocene, bared of their former covering, now merely expose the underlying beds of freestone, while at other points,

not immediately in the line of the violent action of the diluvial wave or current, the incumbent beds of marl remain in place.

Moreover, there is reason to believe that the sandstone is spread out towards the east, below the eocene strata, and that its depth alone conceals it generally from the view. Where, therefore, in consequence of some local irregularity of its surface, it was less deeply buried, we might naturally expect, even at some distance within the confines of the eocene, to see its upper stratum exposed to day. Accordingly, at some points a good deal eastward of the line of boundary, we meet with very distinct exposures of this rock. Of this a good example is presented at Gray's mill, on Muddy creek, near the Rappahannock, where, in a ravine by the road side, may be seen the blue and ferruginous material of the marl, while upon the other side of the road is a ledge of coarse, soft and whitish sandstone, over which the mill-stream flows.

Arrangement and Composition of the Miocene Strata of the Peninsula.

The strata composing the miocene, in this portion of the state, are in general analogous, in arrangement and materials, to those of the same formation in the peninsula of the York and James rivers, as described in our former communication.

The two interesting general facts of the occurrence of the bluish marls low down in the series, and the presence of a thin band of ferruginous rock or clay on the top of the marl, and between it and the diluvial strata, are not less distinctly observable here than in the region formerly referred to. Indeed, so uniform is this position of the band of iron rock, in regard to the beds of marl, that the discovery of this material, at any point, would furnish strong grounds for believing that the fossiliferous strata existed at some depth beneath.

In general, the blue marl is observed to be the richest in fossils, and is hence found most available in agriculture. In many places, however, especially towards the eastern termination of the peninsula, the shells occur in sand and clay of various shades of yellow and brown, in sufficient proportions to form highly valuable marls.

The fragmentary rock, consisting of broken shells, cemented by carbonate of lime, sometimes partially crystallized, and the white, pulve-

ruled and chalk marls, are found in extensive beds on Curratoman river and Carter's creek, west of the termination of the higher level of the neck.

In general, the upper beds of the meiocene, in this district, are destitute of fossils, though full of their casts and impressions. These strata, consisting, for the most part, of light coloured sandy clays, frequently of great depth, are distinguished by a sulphurous smell, and an acid and somewhat styptic flavour. They rarely contain any considerable amount of carbonate of lime, presenting, in its stead, variable and sometimes valuable proportions of the sulphate, together with sulphate of iron, sulphate of alumina, free sulphuric acid, sulphur, and sometimes even an appreciable quantity of sulphate of magnesia.

The acidity of these clays is often sufficient to make a pungent impression on the tongue, and their sulphur is distinctly recognized by the characteristic odour they exhale, especially when gently warmed. In many localities the gypsum occurs in crystals of sufficient magnitude to be readily separated by the fingers, and sometimes even in the attractive form of transparent selenite; but its more usual condition is that of delicate silken crystals, distributed through the mass, and visible only upon close and attentive inspection. The sulphates of iron and alumina are occasionally observed in the form of an efflorescence, upon the surface of the strata, and the gypsum likewise presents itself, under similar circumstances, as a white incrustation. Minute, silvery scales of mica are met with in nearly every stratum, but abound most in those of a bluish or greenish tinge.

The fossil impressions contained in these beds are, in general, beautifully distinct, and appertain to all the species of shells which are found in perfect condition in the subjacent strata. In some cases the overlying band of iron stone is not less richly fraught with them than the layers beneath, and from its hardness and insolubility, has preserved the most delicate markings of the shells in all their original sharpness. In many localities the impressions of the fossils in the clay or sand are beautifully bronzed by a thin film of oxide of iron, which has taken the place of the material of the shell; but in others a vacancy seems to exist in the space originally occupied by the calcareous matter, so that

the interior casts of the fossils, formed of the general substance of the bed, may often be extracted in great numbers in a perfect condition.

In the blue marl, as well as other strata containing fossils, in the neck, there is often present a notable proportion of green sand, and at some localities of the meiocene this material is found mingled pretty largely with common sand and clay, in strata in which no fossils can be found.

Besides the overlying band of ferruginous rock before described, there occurs, in some places in the neck, another similar stratum, nearly on the top of the diluvium. This, of course, presents no marks of organic remains, and is generally but an aggregation of coarse gravel and sand, cemented by ferruginous matter.

Description of some of the more interesting Localities in the Meiocene District of the Peninsula.

To give clearer conceptions of the arrangement and character of the strata, of which a general sketch has just been presented, a detailed account of them, as exhibited at several of the more important localities in the Neck, will now be introduced. Details of this description, whilst they furnish the scientific inquirer at a distance with that precise information in regard to the geological structure of the region which he is chiefly interested to obtain, are not unattended with advantages of a more practical kind, by affording to all who are directly interested in the resources of a district, an easy mean of examining them for themselves.

Stratford and Chantilly Cliffs.

These noted cliffs, situated in Westmoreland county, extend along the Potomac for several miles, on both sides of the mouth of Chantilly creek, rising, in some places, to an elevation of about one hundred feet, and in others subsiding to lower levels, or sinking, for a short space, into the ordinary river flats. At a point a little above the mouth of the creek, what are properly termed the *Stratford cliffs* begin. Thence they continue up the Potomac, with but little interruption, for about four miles. For some distance from their lower termination, they present the following order of strata.

1. At the base, and extending to the height of from fifty to seventy

feet, a stratum of blue sandy clay, containing impressions of shells of several different kinds, among which the *Pecten Madisonius*, *Venus mercenaria*, *Venus cortinaria (nobis)*, and *Macra modicella* are the most frequent. Upon the face of this clay, especially where it projects from the general cliff, a copious efflorescence of sulphate of iron is usually found, imparting a greenish yellow colour to the surface. At other more retiring parts of the cliff, a white, and somewhat granular coating of sulphate of lime, is equally abundant, and small silken crystals of this substance are generally disseminated through the materials of the stratum. On the surface of this bed delicate crystals of sulphate of magnesia may likewise be discerned. This stratum is overlaid by a band of indurated ferruginous clay, approaching to the hardness of rock, and filled with a material closely resembling pipe-stem ore. This is about two feet thick. Next above is a stratum consisting alternately of sand and ferruginous mottled clay, extending to a height of about forty feet; and lastly, is a layer of diluvial gravel, covered with a shallow soil.

Further up the river the cliffs attain a greater elevation, being in some places about one hundred feet in height. Here the same strata occur, and in the same order as before. Proceeding still higher up the river, a band of shells makes its appearance upon the face of the cliff, at a height of about fifteen feet above the water. This rises, as we ascend the river, with a gentle inclination, until at its northern extremity it is fifty or sixty feet above the beach. The width of this band is about five feet, and its length, though not without occasional interruptions, about one and a half miles.

The material of this stratum is a bluish sandy clay, very similar to that before described, but containing no appreciable amount of the various sulphates observed to be present in the former. The shells are very numerous and perfect. Among them are vast numbers of the *Perna maxillata*, of small size, as well as *Turritella plebeia*, *Macra modicella*, &c., with an occasional *Arca idonea*, and other larger shells. Above this bed is a heavy stratum of clay, of a mottled appearance, and higher still, and distant about twenty feet from the former, a second fossiliferous layer, of a lighter colour, and containing fewer shells.

Among the various substances found in the strata of these cliffs, especially towards the lower extremity, are to be enumerated distinct and beautifully compact lignite and fibrous carbonate of lime. The latter is found in the interstices of a yellowish clay, forming the stratum next beneath the diluvium, and is sometimes in sufficient quantity to render the clay quite calcareous.

An average specimen of the blue marl, from the lower of the two strata just described, yielded in the one hundred grains forty-four and three-tenths grains of carbonate of lime ; from the upper only twenty-one grains.

The Chantilly cliffs, situated below the mouth of the creek of the same name, adjoining the ancient residence of Richard Henry Lee, and about two miles further down the river than those of Stratford, may be regarded as a continuation of the former, having the same average elevation, and being composed of very similar materials. At this point, however, the fossiliferous stratum has much greater thickness, sometimes reaching from the water's edge to a height of nearly twenty-five feet. A less proportion of the *Perna* is presented in this bed, which principally consists of *Mastras*, and other small bivalves, together with several species of *Pectens*. The beach is strewn with fragments of ferruginous sandstone, which have fallen from the upper portion of the cliff, where a band of this material overlies the shelly strata of the miocene. These masses exhibit the impressions of *Pectens* and other shells, beautifully clear and sharp.

An interesting illustration of the fertilizing properties of some of the materials composing the Stratford and Chantilly cliffs is deserving of mention in this place. Zones of vegetation, consisting of clover, together with scattered locust trees, may be observed at the proper season extending to a great distance along the face of the cliffs, marking distinctly the limits of the marl or gypseous clay, and rarely encroaching upon the other strata. Even where the surface is almost vertical, this beautiful drapery is retained.

Bank of the Potomac, below the Mouth of Lower Machodoc River, in Westmoreland County.

At Cole's Point, situated on the south side of the mouth of the Lower Machodoc, commences a low bank, which is prolonged for

about one and a half miles down the river, at a pretty uniform elevation of fourteen feet. A few paces below the Point, the following strata occur.

1. A layer two feet thick, consisting of a bright yellow mixture of sand and clay, abounding in shells of various kinds, among which are *Perna maxillata*, *Ostrea compressirostra*, *Venus mercenaria*, *V. cor-tinaria*, *V. paphia*, *Isocardia fraterna*, *Pecten Madisonius*, *P. Jeffersonius*, *Pectunculus pulvinatus*, *Corbula inequale* and *Turritella variabilis*.

2. Next a layer six feet thick, composed of mottled ferruginous sand, with a small admixture of clay, containing no shells, but abundant markings, as if shells had once been present in great numbers.

3. A band of iron sandstone, three inches thick ; and

4. A dark mould, extending to the top.

In proceeding down the Potomac, the yellow marl is seen gradually rising higher in the bank. A stratum of blue marl lying beneath it next comes in view, and this continues along the base of the bank, extending some distance out upon the beach, until the shore sinks into a low sandy flat at Ragged Point.

The Rappahannock cliffs, in Richmond county, nearly opposite to Westmoreland C. H., extend along the river for about four miles, at an average elevation of from forty to sixty feet. Throughout this long range of strata, but little variety is presented. Beds of sandy clay, of various shades of yellow, brown and greenish blue, extend from the water's edge to within a few feet of the top of the bank. In general, the first thirty feet consist of a dark greenish blue mixture of sand and clay, above which is a layer, six feet thick, of similar material, of a brown colour ; next a band of twelve inches of a ferruginous aspect, and over all a stratum of light coloured flaky clay, coated with a yellowish and white incrustation of sulphate of lime. Fossils are rare in any of these beds, but multitudes of their casts and impressions may be found. These embrace a great variety of the smaller shells, some of them of species not frequently met with. Spiculæ of gypsum are distributed in the body of the clay, and are particularly numerous upon the surface and in the hollow of the casts, which in general are painted over with the brown oxide of iron. In many places sulphate of iron

and sulphate of alumina effloresce upon the surface, and sulphur is distinctly indicated.

Irregular nodules of ferruginous clay are found imbedded in the other materials, presenting the curious feature of a crystalline nucleus, consisting of pure selenite. In some portions of the cliff these crystals are of considerable size, arranged in their usual starlike form, and so abundant as to suggest the utility of employing these clays in the agriculture of the neighbouring parts of the neck. An average specimen, taken from a part of the cliff where a similar material was quite abundant, afforded by analysis, in the one hundred grains, ten grains of sulphate of lime.

Banks of the Rappahannock above the Mouth of Curratoman River, Lancaster County.

In proceeding down the river from the neighbourhood of Belmont, the residence of Dr Jones, about eight miles above the mouth of Curratoman, the cliffs, for some distance, present heavy beds of clay and sand, overlaid by the ordinary diluvium, and resting upon a stratum of soft ferruginous sandstone, graduating into a sandy clay, and sometimes a yellowish sand, mottled with ferruginous spots. Following these strata for a distance of one and a half miles, we meet with a rocky layer, consisting entirely of shells, converted into brown oxide of iron, situated at the base of the cliff. This continues in the same direction for a distance of one and a quarter miles. The following is the order of the strata composing the bank at a point near its eastern termination:

1. Beneath the base of the cliff, as it is exposed, and also underlying the beach sand, is a blue marl, containing numerous shells, and having a sensible amount of green sand. These shells are chiefly the *Perna*, different species of *Venus*, *Natica* and *Oliva*.

2. Running along the base of the bank, the ferruginated, shelly rock above described, four feet in thickness, and containing the same fossils as the stratum beneath.

3. Five feet of sand, with ferruginous blotches and streaks.

4. Six feet of diluvium.

Below this, and within a short distance of the Curratoman, marl beds occur below the level of the flats, consisting chiefly of a peculiar

variety of the *Ostrea Virginica*,* of which a similar deposit exists on the opposite side of the Rappahannock. It is distinguished by the length and depth of the channel of the hinge in the valve, and the large angular pivot-like protuberance in the other, as well as by the general elongated form of the shell.

Bank of the Rappahannock from near Cherry Point to Musqueto Point, Lancaster County.

At about one mile above *Cherry Point*, at Mr Palmer's, the bank consists of the following strata:

1. Forming the base of the cliff, and extending up about three feet is a blue clay marl, containing a great many shells. This layer reaches to some depth below, and extends out beneath the sand of the beach.

2. A bed of chocolate coloured clay, imbedding a vast number of the variety of *Ostrea Virginica*, previously described. This is three feet in thickness.

3. A bed of partially decomposed *Serpula*, containing few other fossils, one foot thick.

4. A layer of ferruginous sandstone, in bands, alternating with thin seams of sand. Three feet thick.

5. Ten feet of diluvium.

The above strata, in the order just described, continue down the river for the distance of half a mile, appearing to dip gently towards the bay. The marl is then lost for about two and a half miles, after which it reappears, at intervals, as far down as Musqueto Point. Here the country becomes a sandy flat, and so continues to the bay shore. In the interval of two and a half miles, where no marl is seen, the cliffs, which are from twenty to thirty feet in height, consist at the base of blue clay, containing impressions of shells; above this of ferru-

* The variety here referred to has not been found at any other points in the meiocene district but those above enumerated, a circumstance which, together with its close resemblance to the edible *Ostrea Virginica* of the coast, and its place of deposit being so near the extremity of the peninsula, would favour the idea of its belonging either to the modern period, or to a more recent tertiary epoch than the meiocene. This view, however, can scarcely be reconciled with the fact that the shell in question occurs beneath, and associated with, the usual fossils of the meiocene, and that the latter have been found in several places beneath the surface of the flats, still nearer to the bay shore.

ginous sandstone, or of ferruginous sand and clay; the whole covered with a bed of diluvium.

Near the end of this line a blackish, clayey substance rises into view, from the base of the cliff, underlying the blue clay above mentioned. This gradually becomes more exposed upon the bank, until it attains the height of four feet, after which it slowly sinks, and is again lost. The marl now makes its appearance, consisting of a blue clay, with little sand, and multitudes of shells. This reaches along the bank for about four hundred yards, when it is succeeded by a shell rock, in which the shelly fragments are almost completely replaced by brown oxide of iron. This continues to near the end of the bank, which now subsides into the flat, extending from Musqueto Point to Windmill Point, on the bay shore.

Locality one and a half Miles east of Lancaster Court House—Mr Benjamin Walker's.

This exposure, which is in a ravine on the ridge of the neck, presents the following strata :

1. A bed of blue marl, containing great numbers of shells, many of which are of the larger species. The depth of this stratum is not known.

2. A similar stratum of a rather lighter colour, and containing chiefly the small shells. Three feet thick.

3. A layer of ferruginous matter, abounding in the casts and impressions of shells. These casts are usually found in the interior of spheroidal nodules or geodes of oxide of iron, and consist of this oxide, replacing the shelly matter, and covered with a beautiful shining covering of the carbonate or velvet iron ore. This bed is four feet thick, and reaches to the surface.

Locality four Miles south west from Northumberland Court House—Mr George Booth's.

This exposure is in a hollow, about twenty-five feet below the level of the ridge. The strata are :

1. A layer of greenish blue marl, containing a notable amount of green sand, in spots and blotches, and sometimes almost unmixed with other materials. This stratum has been penetrated five or six feet, and is supposed to extend to a much greater depth. The shells

are in a state of remarkably perfect preservation, and present an unusual variety of species, belonging to the genera *Venus*, *Pecten*, *Pectunculus*, *Mastra*, *Crassatella*, *Astarte*, *Ostrea*, *Corbula*, *Turritella*, *Oliva*, *Fissurella*, and others. Their interior is chiefly filled with the green sand.

2. A layer of ferruginous sandstone; and
3. A stratum of diluvium.

Locality at Cockle-Shell Branch, Northumberland County.

Here the strata are :

1. A bed of marl, consisting of common sand mixed with green sand, and containing a large number of shells.
2. A layer of a bright green indurated sandy clay, approaching to the hardness of rock, and containing innumerable impressions of *Venericardia granulata*, *Pectunculus pulvinatus* and *P. subovatus*, and other shells of rare delicacy and beauty, but entirely devoid of the shells themselves.
3. A bed of common sand, largely mixed with green sand.
4. A layer of sandy clay, with markings resembling shells.
5. Diluvium.

Locality two and a half Miles above the Mouth of Hull's Creek, Northumberland County.

1. At the base of the steep bank of the creek, and within a few inches of the water's edge, occurs a ledge of ferruginous rock, containing an immense number of shells, closely cemented together, as well as the casts of similar fossils. These are chiefly *Perna max.*, *Venus* and *Pecten*. This ledge is two feet thick.
2. A stratum of yellowish sandy clay, of the same thickness, abounding in *Perna max.*, in a very friable condition.
3. A light blue marbled clay, ten feet.
4. Coarse diluvium.

The foregoing detailed account of various localities in the neck will, it is hoped, give a correct idea of the generally prevailing order and fossil contents of the meiocene strata in this district, and at the same time exemplify the principal varieties presented in them, as regards

the nature of the earthy materials, including the shells, or their casts, as well as the conditions of the fossils themselves. Of the numerous other localities which have been minutely explored, embracing almost every exposure of the meiocene in the peninsula, it is therefore needless to give any description in this place.

In the extensive area of flats already described as reaching from the foot of the ridge of which Sprize Hill is the northern end, to the bay shore, beds of marl have hitherto been disclosed only at a few points. On the land of W. Tomlin, Esq., near Kilmarnock, blue and yellow marls have been found in several places, a few feet beneath the general level of the flat, and it is particularly worthy of remark that the fossils furnished by these shallow diggings are those usually found in the meiocene of the neck, such as *Ostrea compressirostra*, *Pectunculus pulvinatus* and *P. subovatus*, *Mactra modicella*, &c., thus indicating the prolongation of the meiocene strata to the very extremity of the peninsula.

Of the Fossils of the Marl.

The shells enclosed in these strata are usually in good preservation, though generally so friable as readily to fall to pieces when spread upon the ground. They are commonly found in groups or colonies, and frequently throughout an extensive exposure only one or two species can be met with. This is strikingly the case with the beds containing *Perna*, of which a fine example is presented in the Stratford cliffs, as formerly described. It is perhaps still more remarkable of certain strata of blue marl, found on the Potomac, at the point above named; upon the Rappahannock in several places, and at some localities in the interior. This marl presents a beautiful aggregation of very perfect small shells (*Mactra modicella*), bound together by a rather tenacious blue clay, and rarely exhibits a specimen of any other species.

The shells most usually presented in the marl beds of the neck are as follows:

<i>Pecten Jeffersonius</i> , scallop.	<i>Arca idonea</i> .
“ <i>Madisonius</i> , “	“ <i>stillicidium</i> .
<i>Ostrea compressirostra</i> , marl	“ <i>centenaria</i> .
oyster.	“ <i>incile</i> .
<i>Ostrea Virginica</i> , marl oyster, of	<i>Venus mercenaria</i> .
small size and different shape.	“ <i>deformis</i> .
<i>Crassatella Marylandica</i> , marl	“ <i>cortinaria</i> .
oyster.	<i>Astarte undulata</i> .
“ <i>melina</i> .	“ <i>vicina</i> .
<i>Macra delumbis</i> .	<i>Venericardia granulata</i> .
“ <i>confraga</i> .	<i>Fusus quadricostatus</i> .
“ <i>modicella</i> .	“ <i>parilis</i> .
<i>Chama corticosa</i> .	<i>Fulgur carica</i> .
“ <i>congregata</i> .	<i>Turritella ter-striata</i> .
<i>Pectunculus subovatus</i> .	“ <i>alticosta</i> .
“ <i>pulvinatus</i> .	“ <i>plebeia</i> .
<i>Perna maxillata</i> .	<i>Serpula granifera</i> .
<i>Isocardia fraterna</i> .	<i>Crepidula costata</i> .
<i>Artemis acetabulum</i> .	<i>Buccinum laqueatum</i> .

Arrangement and Composition of the Eocene Strata of the Peninsula.

But little uniformity prevails in the arrangement of these beds, as observed at different localities. In general, the lowest stratum of the series is of a dark greenish blue colour, and those which lie above it have various shades of yellow, greenish gray and brown. In many instances the upper stratum is devoid of shells, but replete with their casts and impressions. Frequently it is more or less impregnated with sulphates of lime, iron and alumina, which impart to it a styptic or astringent flavour, and with a small amount of sulphur, recognized by the odour it exhales when heated. All these ingredients, however, enter into the lower beds, though in less proportion, and are not excluded from strata containing shells. A thin band of ferruginous gravel, sometimes partially cemented, frequently overlies these beds, and forms the boundary between them and the miocene.

We thus see a striking correspondence in the situation and condi-

tion of these and the upper meiocene strata, and we infer that chemical agencies of a like nature have operated upon both.

Localities on the Potomac.

Extensive and valuable exposures of the eocene are met with on this river. These strata first show themselves a little above the mouth of Acquia creek, and continue, with but few considerable interruptions, as far as the eastern boundary of this deposit, at Mathias's Point.

Throughout much of this distance a portion of the marl has the character of a hard rock, of a yellowish white or greenish gray appearance, abounding in shells and their impressions. The lighter coloured variety is always more or less specked with green sand, in rather large granules, and the darker contains this substance in larger quantity, uniformly diffused throughout the mass. The material enclosing the fossils, or their casts, consists largely of carbonate of lime, acting, apparently, as a cement. This rock may therefore be regarded as an eocene limestone.

At a point about a quarter of a mile below the mouth of Acquia creek, the cliff, having a height of forty feet, exposes the following strata:

1. From the water to the height of twelve feet is a yellowish gray marl, specked with green sand, and abounding in shells, chiefly *Cytherea ovata* (*nobis*) and *Crassatella* (*nobis*).

2. A ledge of rock, three feet in thickness, closely resembling the marl in colour and composition.

3. A layer of sandy clay, of a sulphur colour, containing shells, principally *Turritella Mortoni*. This is five feet thick.

4. A stratum of yellowish clay enclosing impressions of *Turritella*, &c., and impregnated with the sulphates. This is twenty feet thick.

About midway between the mouths of Acquia and Potomac creeks, the bank has an elevation of about fourteen feet, and consists of:

1. A layer of dark greenish blue marl, very remarkable for the multitude of shells, principally *Crassatella* (*nobis*), which it contains. This rises only one foot above the water.

2. A bed of shell rock, resembling the stratum beneath, but very hard. One and a quarter feet thick.

3. A layer of yellow sandy clay, containing *Turritella Mortoni*, and other shells. This is at least seven feet in thickness, and is capped by a thin stratum of yellow clay.

In proceeding downwards, the shell rock, dipping gently to the east, becomes lower in the bank, and at length disappears near the mouth of Potomac creek. The bluish marl continuing beneath, first passes out of view.

The greenish blue marl again comes in view at the landing on the south side of Potomac creek, and still further down, at about half a mile below the mouth of Paspitansy creek, the bank of the Potomac presents:

1. A stratum of this dark coloured marl, seven feet thick, containing some green sand and numerous shells, chiefly *Turritella Mortoni*, *Crassatella (nobis)* and *Ostrea*.

2. A bed of yellowish and reddish clay, thirteen feet thick.

A little below this point a ledge of the shell rock makes its appearance in the bank, and continues, with but little interruption, down the river for several miles.

At some points, two of these ledges are seen, one near the water level, and one at a considerable height on the face of the bank. This rock is replete with fossils and their casts, and consists, in large part, of carbonate of lime. In the same bank the marl is seen in the softer condition, and of both the yellowish and greenish blue varieties, overlaid by a stratum of the gypseous and acid clay. Among the interesting fossils here found, are two beautiful species of *Cucullæa*.

At the Eagle's Nest and Mount Stuart, about three miles above Boyd's Hole, the eocene strata are well exposed for some distance along the river bank.

At the former locality, the banks, which are from twenty to twenty-five feet in height, are composed of two strata, the lower, which is about twelve feet thick, consisting of dark bluish clay and sand strongly imbued with copperas and containing a little gypsum, and the upper of coarse ferruginous sand and gravel. A few hundred yards below this point a thin layer, containing fossils, comes in view, about midway between the top and bottom of the bank, and as we proceed down the river this shelly stratum expands in thickness, its upper boundary con-

tinuing horizontal, while its lower limit approaches the level of the beach. At a point about four hundred yards below the beginning of this layer the strata are as follows:

1. Blue clay, one foot in thickness.
2. Shelly stratum, seven feet thick, indurated in some places so as to form a rock. This abounds in fossils, among which *Carditas* are most numerous.
3. Blue clay, containing copperas, and showing ferruginous stains. Three feet thick.
4. Clay and sand, in part diluvial. Seventeen feet thick.

For upwards of half a mile below this the bank presents the same series, the marl occasionally, at base, a stratum from four to seven feet thick, consisting of blue clay, sometimes fossiliferous and sometimes without shells, covered by a bed of ferruginous sand and clay, of varying thickness.

At Boyd's Hole the shelly stratum is not seen, but further down, especially at Albion, and the other localities near Mathias's point, before described, it again makes its appearance in the cliffs (and furnishes marls of a very useful quality).

On the Rappahannock, opposite Port Royal, at H. L. Carter's, and other localities on and near this river, the eocene occurs under circumstances very similar to those which have been described. In the interior of the peninsula these strata are revealed in many places at the bottoms of the deep ravines, and in general consist of the dark greenish blue stratum, containing shells, overlaid by a bed of the gypseous and copperas clays. Frequently, however, only this latter bed is exposed in these situations, and some digging becomes necessary to reach the layer containing shells.

Towards the western limits of the eocene, the shell rock very frequently presents itself, and, together with the other strata of the formation, generally attains a greater height than in the localities further to the east.